AF/3677

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

Appl. No. : 09/943,321 Confirmation No. 8735
Appellant : Stuart A. Sanders et al.
Filed : August 30, 2001
TC/A.U. : 3677
Examiner : Andre L. Jackson

Docket No. : F-7944(01-414)
Customer No. : 34704

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313

APPEAL BRIEF

Sir:

This is an appeal to the Board of Patent Appeals and Interferences from the final rejection dated August 11, 2003, made by the Primary Examiner in Tech Center Art Unit 3677.

REAL PARTY IN INTEREST

The real party in interest is United Technologies Corporation of Hartford, Connecticut.

RELATED APPEALS AND INTERFERENCES

There are no other appeals or interferences known to Appellants, Appellants' legal representative, or assignee which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

STATUS OF CLAIMS

Claims 1 - 24 are pending in the application. Claims 1 - 15 and 17 -24 stand rejected and are on appeal. Claim 16 has been allowed. A true copy of these claims is attached hereto in Appendix A.

Claims 25 - 44, originally in the application, have been cancelled since they are directed to a non-elected invention.

STATUS OF AMENDMENTS

No amendment was filed after final rejection.

SUMMARY OF INVENTION

The present invention relates to an air seal for use in a gas turbine engine. The air seal includes a seal substrate and an abradable seal layer, which abradable seal layer is composed of densified polyimide foam, preferably a thermomechanically densified polyimide foam. See page 3, lines 17 - 22 of the specification.

According to another aspect of the invention, a gas turbine engine seal system is disclosed. The system broadly comprises a seal assembly having a seal substrate and an abradable seal material applied to a bond layer. The abradable seal material is composed of a densified polyimide foam. The system further

comprises an engine component adapted for motion relative to the seal assembly and having an abrasive portion interacting with the abradable seal material. The abrasive portion of the engine component and the abradable seal material of the seal assembly cooperate to provide sealing. See page 3, lines 23 - 32 of the specification.

An air seal for use in a gas turbine engine is shown in FIG. 1. The air seal cooperates with an engine component adapted for motion relative to the seal and has an abrasive portion interacting with the abradable seal material layer to provide sealing. For example, the air seal may be used as an outer air seal (4) between the tip of a rotating vane or blade (2) and a case or housing (3). It may also be used as a knife edge seal (7) positioned between a portion (6) of a stator vane (5), such as a stator box, and a rotating disk tip portion (8). See page 4, line 25 to page 5, line 3 of the specification.

The seal may be formed using any suitable commercially available polyimide foam as a starting material, such as one available from Imi-Tech having an initial density of about 0.4 pounds per cubic foot. The starting material may have one or more layers of polyimide foam. See page 5, lines 4 - 13 of the specification.

The polyimide foam starting material is subjected to a densification treatment to increase the density of the polyimide foam from 0.4 pounds per cubic foot to a density greater than 10 pounds per cubic foot, such as from 12 pounds per cubic foot to 25 pounds per cubic foot. Preferably, the density of the polyimide foam is greater than 15 pounds per cubic foot. The densification treatment should also increase the shear strength of the polyimide foam to be in the range of from 140 psi to 325 psi. See page 5, lines 14 - 21 of the specification.

While the densification treatment may be any suitable densification treatment known in the art, it is preferred to use a thermomechanical densification treatment. In this treatment, the polyimide foam is heated to a temperature greater than 550 degrees F and then compressed for a time sufficient to obtain the desired density and shear strength.. See page 5, lines 22 - 29 of the specification.

After the polyimide foam material has been densified, it may be cut to any desired height, length and width. The polyimide foam material is then bonded to a substrate such as one formed from a metallic material, such as a nickel-based, cobalt-based, or iron-based superalloy, or a polymer composite material such as a graphite-reinforced polyimide. The substrate is preferably an engine component such as a stator box (6) or a

portion of the case (3). The polyimide foam material may be bonded to the substrate by a bonding layer formed from a suitable adhesive material. For example, one or more strips of a polyimide film adhesive may be placed on a surface of the polyimide foam material or a surface of the substrate. Depending on the location of the adhesive material strip(s), the polyimide foam material or the substrate may be placed in contact with the adhesive material strip(s). Thereafter, the adhesive may be cured by applying heat and/or pressure to create a strong bond between the polyimide foam material and the substrate and thus form an air seal having an abradable seal layer composed of a densified polyimide foam. See page 5, line 30 to page 6, line 15 of the specification.

Referring now to FIG. 2, it has been found that when the air seal (4,7) is formed from a plurality of layers (20) of densified polyimide foam material and has a plurality of lamination planes (22) perpendicular to the lamination direction (24), the air seal (4,7) should be installed so that the lamination planes (22) are substantially perpendicular to the centerline (26) and the axial direction (28) of the engine and substantially parallel to the radial direction (30) of the engine. Even if only a single layer of densified foam is used, the seal should be oriented in this way. This is because the

densification process itself results in the formation of fault planes. See page 7, lines 21 - 31 of the specification.

The laminated air seal (4,7) has fault planes defined by its lamination planes (22). The orientation of the fault planes relative to the plate seal motions as shown in FIG. 3. See page 8, lines 1 - 3 of the specification.

As can be seen from the foregoing summary, an air seal (4, 7) has been provided which has an abradable seal layer formed from one or more layers of a densified polyimide material. The abrasive portion of the engine component and the abradable seal layer cooperate to provide the desired level of sealing. See page 8, lines 4 - 8 of the specification.

An advantage of the present invention is that the air seal provides both acceptable durability and abradability, and provides these characteristics at higher temperatures. In addition, the air seal of the present invention is cost effective, relatively simple to fabricate, and does not weigh any more than conventional seal materials. See page 8, lines 17 - 22 of the specification.

REFERENCES RELIED UPON BY THE EXAMINER

Patent No.	Patentee	Issue Date
5,388,959	Forrester et al.	February 14,1995
6,475,253	Culler et al.	November 5, 2002
3,834,001	Carroll et al.	September 10, 1974

REJECTIONS OF RECORD

1. Claims 1, 2, 4 - 14, and 17 - 24 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Forrester et al. in view of Culler et al.

2. Claims 3 and 15 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Forrester et al in view of Culler et al. and further in view of Carroll et al.

ISSUES

1. Are the Forrester et al. and Culler et al. references properly combined given the fact that Culler et al. is from non-analogous art?

2. If properly combined, do the Forrester et al. and Culler et al. references teach or suggest the limitations of claims 1, 2, 4 - 14, and 17 - 24?

3. Does the combination of Forrester et al., Culler et al., and Carroll et al. teach or suggest the limitations of claims 3 and 15?

GROUPING OF CLAIMS

Each of the claims 1 - 15 and 17 - 24 is independently patentable. None of the claims stand or fall together.

ARGUMENT

(a) CLAIMS 1, 2, 4 - 14, AND 17 - 24 ARE ALLOWABLE OVER FORRESTER ET AL. AND CULLER ET AL.

The Forrester et al. patent relates to a fan assembly (5) for a gas turbine engine having a stator casing (10) made of a first material and an annular abradable seal structure (22) made of a second material. The seal structure (22) has an abradable inner annular surface (24) against which is juxtaposed tips (26) of fan blades (28) of rotor (30).

As shown in FIG. 3 of the Forrester et al. patent, the second material comprises a sheet (42) of epoxy foam including

chopped fiberglass reinforcing fibers and microballoons. The sheet (42) is directly bonded to the inner annular surface (41) of the inner annular grooves (20) of the casing (10). The sheet (42) serves as an abradable seal structure and provides abradable seal surface (24). The composition of the sheet (42) is selected to have a coefficient of thermal expansion which is moderately greater than the metal of the casing. The fiberglass fibers are randomly disposed and oriented to provide internal structural support to the sheet.

As stated by Forrester et al. at column 3, line 14 et seq., "[d]uring cure, epoxy foam material (42) expands to fill and conform to the shape of the groove (20). It is cured and self-bonded to the groove (20) at 30 psi and 250 degrees F for two hours. The epoxy foam material (42) has a density of 25 pounds per cubic foot".

Claim 1 in the instant application calls for the abradable seal layer to be composed of a densified polyimide foam. Forrester does not teach or suggest forming the abradable seal layer from such a material. Acknowledgement of this by the Examiner can be found on page 2, lines 8 - 9, of the rejection.

Recognizing the foregoing deficiency, the final rejection made by the Examiner cites Culler et al. as teaching:

> "... abrasive articles including substrates or particles bonded thereto (column 19, lines 47 - 66). These

> abrasive articles can be bonded, coated or non-woven abrasive articles. Suitable material for coated or bonded articles may include polymeric foam. Culler et al. goes further to give information of various types or equivalent composition of polymeric material, which includes a polyimide film. Since the epoxy foam as disclosed by Forrester et al. is equivalent to a polyimide foam taught by Culler et al., the selection of any of these known equivalents bonded to a layer as claimed would be within the level of ordinary skill in the art."

A review of the Culler et al. patent shows that it comes from non-analogous art. Culler et al. does not relate in any way to the formation of an abradable structure for use in a gas turbine engine. Instead Culler et al. relates to the manufacture of a product which has no utility in gas turbine engines - namely, a coated, bonded or non-woven abrasive article containing precisely shaped particles and a binder. Culler identifies one of the products as being a grinding wheel having grit particles. With regard to the portion of Culler et al. beginning at column 19, line 60 et seq., Culler et al. are talking about various backings suitable for preparing coated abrasive articles. The backings include polymeric film, primed polymeric film, cloth, paper, vulcanized fibers, polymeric foam, nonwovens, treated versions thereof, and combinations thereof. Examples of polymeric films which can be used for the backings include polyester film, polyolefin film, polyamide films, polyimide films, and the like. FIGS. 4 and 5 in Culler et al. show an abrasive article prepared in accordance with Culler et

al.'s teaching. The abrasive surface comprises abrasive particles (106) bonded to the backing (104) and a coating (108) applied over the abrasive particles. The abrasive particles comprise a plurality of abrasive grits and a binder. Thus the abradable surface in Culler et al. is definitely not formed by a polyimide film. Still further, Culler et al. never says that any polyimide film that is used is a "densified polyimide film".

To establish obviousness, the Examiner must do more than identify the elements in the prior art. There must also be some objective teaching in the prior art or knowledge generally available to one of ordinary skill in the art which would lead an individual to combine the relevant teachings of two cited references. See *In re Fine*, 5 USPQ2d 1596, 1598 (Fed. Cir. 1988). The motivation, suggestion or teaching may come explicitly from statements in the prior art, the knowledge of one of ordinary skill in the art, or in some cases, the nature of the problem to be solved. See *In re Kotzab*, 55 USPQ2d 1313, 1317 (Fed. Cir. 2000). It is submitted that the required motivation, suggestion or teaching is missing from the cited and applied references. As stated above, Culler et al. is from non-analogous art and has nothing to do with the formation of abradable seal layers for use in gas turbine engines or elsewhere. Further, Culler et al. does not teach or suggest

forming an abradable seal layer from a "densified polyimide foam". Nowhere in any discussion of Culler et al. does the Examiner point to a place which talks about densified polyimide foam. Still further, assuming arguendo that Culler et al. teaches the claimed material, there is nothing in Culler et al. which would lead one of ordinary skill in the art to select such a material from the laundry list of materials presented in Culler et al.

For these reasons, claim 1 is allowable over the combination of Forrester et al. and Culler et al.

Claim 2 is allowable because neither of the cited and applied references teach an abradable seal layer having at least one layer of the densified polyimide foam.

Claims 4 and 19 are allowable because neither of the references teaches the use of a polyimide foam having a density of at least 10 pounds per cubic foot. Culler et al. is entirely silent as to the density of the polyimide foam that is used for the backing, not the abrasive surface. As for the Examiner's comments about Forrester's density, the Examiner forgets that the rejection is to replace the epoxy foams of Forrester.

Claims 5 and 20 are allowable because neither of the references teaches the use of a polyimide foam having a density of at least 15 pounds per cubic foot. Culler et al. is entirely

silent as to the density of the polyimide foam that is used for the backing, not the abrasive surface. As for the Examiner's comments about Forrester's density, the Examiner forgets that the rejection is to replace the epoxy foams of Forrester.

Claims 6 and 21 are allowable because neither of the references teach the use of a polyimide foam having a density in the range of 12 to 25 pounds per cubic foot. Culler et al. is entirely silent as to the density of the polyimide foam that is used for the backing, not the abrasive surface. As for the Examiner's comments about Forrester's density, the Examiner forgets that the rejection is to replace the epoxy foams of Forrester.

Claims 7 and 22 are allowable because neither of the cited and applied references teach or suggest using a polyimide foam having a shear strength of 140 psi to 325 psi. Culler et al. is entirely silent as to the shear strength of the polyimide foam material used for the backing.

Claims 8 and 17 are allowable because neither of the cited and applied references teaches or suggests a seal substrate comprising a polymer composite. The casing (10) in Forrester et al. is formed from aluminum.

Claim 9 is allowable because neither of the cited and applied references teaches or suggests that the air seal is an outer seal.

Claim 10 is allowable because neither of the cited and applied references teaches or suggests that the air seal is a knife edge seal.

Claims 11 and 18 are allowable because neither of the cited and applied references teaches or suggests the use of a thermomechanically densified polyimide foam. With regard to the Examiner's comments about claim 11 on page 3 of the office action, the Examiner forgets that the epoxy foam is being replaced in the rejection. Further, there is nothing in Forrester et al. that says that the foam is a thermomechanically densified foam material. These words can not be found in Forrester et al. and the Examiner has not stated how he reaches the conclusion that Forrester et al's foam is a thermomechanically densified foam material from the words in the cited portion of Forrester et al.

Claim 12 is allowable because neither Forrester et al. nor Culler et al. teach or suggest an abradable seal layer applied to a bond layer, which abradable seal layer is composed of a densified polyimide foam. In Forrester et al., the epoxy foam material is bonded directly to the casing (10) without any bond

layer. As discussed above in connection with claim 1, neither Forrester et al. nor Culler et al. teaches the use of a densified polyimide foam. Even if Culler et al. taught such a material, it does not teach it being applied to a bond layer.

Claim 13 is allowable because neither of the references teaches that the seal substrate comprises a stator box and the engine component comprises a disk. Forrester et al. shows a seal for a fan used in a gas turbine engine. The Examiner has failed to grasp that the terms "stator box" and "disk" have a particular meaning in connection with gas turbine engines - in other words, that they are particular engine components which are not described in either Forrester et al. or Culler et al.

Claim 14 is allowable because neither Forrester et al. nor Culler et al. teach or suggest using the claimed seal in connection with a seal substrate and a rotatable vane. In the gas turbine engine art, a fan blade is not considered to be a rotatable vane.

Claim 23 is allowable because neither Forrester et al. or Culler et al. teach or suggest forming a bond layer from at least one adhesive strip. As discussed above, in Forrester et al., the epoxy foam material adheres directly to the aluminum casing.

Claim 24 is allowable because neither Forrester et al. or Culler et al. teach or suggest forming a bond layer from a layer of adhesive material. As discussed above, in Forrester et al., the epoxy foam material adheres directly to the aluminum casing.

The citation of the *Masham* case is duly noted; however, the Examiner misses the thrust of Appellants' arguments. The argument again is that there is nothing in Culler et al. which would teach or suggest using the claimed densified polyimide foam as an abradable seal layer in a gas turbine engine and/or the other claimed components not found in Forrester et al. In Culler et al., there is a long laundry list of materials which can be used for the backing of the abrasive articles formed by Culler et al. such as a grinding wheel. Appellants find nothing in Culler et al. which talks about the use of densified polyimide foams in an abradable seal structure. Given this fact, Appellants do not find anything in Culler et al. which would teach or suggest or motivate one to use a densified polyimide foam in the claimed abradable seal structure. The fact that a particular material such as polyimide foam may exist in the prior art is insufficient to establish obviousness as pointed out in the *Fine* case. Further, it should be noted that the Examiner's beliefs are not the standard of determining

obviousness. The issue of obviousness is strictly determined from the teachings of the references.

(b) CLAIMS 3 AND 15 ARE ALLOWABLE

Claim 3 is allowable because none of the cited and applied references teach or suggest an abradable seal layer comprising a plurality of layers of said densified polyimide foam. Carroll et al. may disclose the use of a plurality of layers; however, none of these layers are formed from the claimed densified polyimide foam. Consequently, Carroll et al. does not cure the deficiencies of Forrester et al. and Culler et al. Nor does Carroll et al. teach or suggest the subject matter of claim 3.

Claim 15 is allowable because none of the cited and applied references teaches or suggests forming the abradable seal material from a plurality of layers of the densified polyimide foam having a lamination plane which is substantially perpendicular to the centerline.

(c) RESPONSE TO EXAMINER'S COMMENTS IN ADVISORY ACTION

On November 25, 2003, the Examiner issued an advisory action which contains a number of comments which must be addressed by Appellants.

First, on page 2, first paragraph of the advisory action, the Examiner contends for the first time that Forrester inherently meets all of the claimed limitations of Appellants' claims. The Examiner has not provided any explanation as to how Forrester does this. The fact of the matter, as discussed above, Forrester fails to meet many of the claimed limitations. Most notably, Forrester does not teach or suggest the use of a densified polyimide foam.

As for the Examiner's comments about Culler et al. in the same paragraph, the comments only highlight the fact that the Examiner still does not understand that Culler et al. does not bond any densified polymer resin to any surface. As noted above, in Culler et al., the plastic materials are used to form the backing to which abrasive grits are applied and bonded. The plastic materials themselves are never bonded to any surface. Culler et al. is non-analogous art. As for the contention that Culler et al. discloses densified polymer resins, Appellants can not find any such teaching in Culler et al. If the Examiner believes it is there, he should point to it directly.

With regard to the second paragraph on page 2, the Examiner could take the position of using Forrester et al. as an obvious type rejection alone, but the Examiner has not taken such a position in the final rejection and it would be incorrect. As

for the statement about the material in Forrester et al. being a matter of art recognized equivalents, the Examiner has not made such an argument in the final rejection from which this appeal is taken.

With regard to the research done by the Examiner, Appellants have no idea what this research is because the Examiner has not provided Appellants with the details of the research. In other words, Appellants have no idea what it is that the Examiner located at to reach his conclusion. The Examiner certainly has not identified any prior art materials or case law that he is relying on. In fact, he has not identified the sources from which the alleged facts come from. Thus, the Examiner's comments and conclusion should be ignored by the Board.

CONCLUSION

For the foregoing reasons, the Board is hereby requested to reverse the rejections of record and remand the instant application back to the Examiner for allowance.

APPEAL BRIEF FEE

The Commissioner is hereby authorized to charge the fee of $330.00 for the instant Appeal Brief to Deposit Account No.

21-0279. Should the Commissioner determine that an additional fee is due, he is hereby authorized to charge said additional fee to said Deposit Account.

Respectfully submitted,

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IN TRIPLICATE

Date: January 12, 2004

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313" on January 12, 2004.

Nicole Motzer

APPENDIX

1. An air seal for use in a gas turbine engine having improved durability, comprising:

a seal substrate; and

an abradable seal layer on the seal substrate, said abradable seal layer being composed of a densified polyimide foam.

2. An air seal according to claim 1, wherein said abradable seal layer has at least one layer of said densified polyimide foam.

3. An air seal according to claim 1, wherein said abradable seal layer comprises a plurality of layers of said densified polyimide foam.

4. An air seal according to claim 1, wherein said polyimide foam has a density of at least 10 pounds per cubic foot.

5. An air seal according to claim 1, wherein said polyimide foam has a density of at least 15 pounds per cubic foot.

6. An air seal according to claim 1, wherein said polyimide foam has a density in the range of from 12 pounds per cubic foot to 25 pounds per cubic foot.

7. An air seal according to claim 1, wherein said polyimide foam has a shear strength of 140 psi to about 325 psi.

8. An air seal according to claim 1, wherein said seal substrate comprises a polymer composite.

9. An air seal according to claim 1, wherein the air seal is an outer air seal.

10. An air seal according to claim 1, wherein the air seal is a knife edge seal.

11. An air seal according to claim 1, wherein the densified polyimide foam is a thermomechanically densified polyimide foam.

12. A gas turbine engine seal system comprising:

a seal assembly having a seal substrate and an abradable seal material applied to a bond layer;

said abradable seal material being composed of a densified polyimide foam; and

an engine component adapted for motion relative to the seal assembly and having an abrasive portion interacting with the abradable seal material, whereby the abrasive portion of the engine component and the abradable seal material of the seal assembly cooperate to provide sealing.

13. A gas turbine engine seal system according to claim 12, wherein said seal substrate comprises a stator box and said engine component comprises a disk.

14. A gas turbine engine seal system according to claim 12, wherein said seal substrate comprises a portion of a case and said engine component comprises a rotatable vane.

15. A gas turbine engine seal system according to claim 12, wherein:

said engine component forms part of an engine having a centerline;

said abradable seal material comprises a plurality of laminated layers of said polyimide foam having a lamination plane; and

said lamination plane is substantially perpendicular to said centerline.

16. A gas turbine engine seal system comprising:

a seal assembly having a seal substrate and an abradable seal material applied to a bond layer;

said abradable seal material being composed of a densified polyimide foam;

an engine component adapted for motion relative to the seal assembly and having an abrasive portion interacting with the abradable seal material, whereby the abrasive portion of the engine component and the abradable seal material of the seal assembly cooperate to provide sealing;

said engine component forming part of an engine having a centerline;

said abradable seal material comprising a plurality of laminated layers of said polyimide foam having a lamination plane;

said lamination plane being substantially perpendicular to said centerline; and

said lamination plane being substantially parallel to a radial direction of said engine and substantially perpendicular to an axial direction of said engine.

17. A gas turbine engine seal system according to claim 12, wherein said seal substrate comprises a component formed from a polymer composite.

18. A gas turbine engine seal system according to claim 12, wherein said densified polyimide foam comprises a thermomechanically densified polyimide foam.

19. A gas turbine engine seal system according to claim 12, wherein said polyimide foam has a density of at least 10 pounds per cubic foot.

20. A gas turbine engine seal system according to claim 12, wherein said polyimide foam has a density of at least 15 pounds per cubic foot.

21. A gas turbine engine seal system according to claim 12, wherein said polyimide foam has a density in the range of from 12 pounds per cubic foot to 25 pounds per cubic foot.

22. A gas turbine engine seal system according to claim 12, wherein said polyimide foam has a shear strength in the range of 140 psi to 325 psi.

23. A gas turbine engine seal system according to claim 12, wherein said bond layer is formed by at least one adhesive strip.

24. A gas turbine engine seal system according to claim 12, wherein said bond layer is formed by a layer of adhesive material.